REPLACED BY ART 34 AMDT

ESTIMATING THE OPERATING POINT ON A NONLINEAR TRAVELING WAVE TUBE AMPLIFIER

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. §119(e) of the following U.S. Provisional Patent Applications, which are incorporated by reference herein:

[0002] U.S. Provisional Patent Application No. 60/421,289, filed October 25, 2002 by Ernest C. Chen and Shamik Maitra, entitled "ESTIMATING THE OPERATING POINT ON A NONLINEAR TRAVELING WAVE TUBE AMPLIFIER", attorney's docket number PD-202131 (109.99-US-P1); and

[0003] U.S. Provisional Patent Application No. XX/XXX,XXX, filed on October 10, 2003, by Ernest C. Chen, entitled "IMPROVING TWTA AM-AM AND AM-PM MEASUREMENT", attorney's docket number PD-202118 (109.104-US-P1).

[0004] This is a continuation-in-part application and claims the benefit under 35 U.S.C. §120 of the following co-pending and commonly-assigned U.S. utility patent applications, which are incorporated by reference herein:

[0005] Utility Application Serial No. 09/844,401, filed April 27, 2001, by Ernest C. Chen, entitled "LAYERED MODULATION FOR DIGITAL SIGNALS," attorneys' docket number PD-200181 (109.51-US-01); and

[0006] U.S. Application Serial No. 10/165,710, filed on June 7, 2002, by Ernest C. Chen, entitled "SATELLITE TWTA ON-LINE NON-LINEARITY MEASUREMENT," attorney's docket number PD-200228 (109.55-US-01).

BACKGROUND OF THE INVENTION

1. Field of the Invention

[0007] The present invention relates to systems and methods for transmitting data, and in particular to a system and method for estimating a traveling wave tube amplifier operating point to accurately reproduce transmitted signals.

refers to the reconstructed clean signal before the imposition of TWTA nonlinearity. The RMS value identifies the input operating point on the measured nonlinearity curves.

[0116] The output operating point is then obtained at step 1306 (e.g., as a byproduct of the non-linearity measurement data). The output operating point may be obtained using a variety of methods. For example, the output operating point may be calculated from the RMS value of the output (received) values used to determine the TWTA non-linearity curve (e.g., when matching the curve as described below) less the estimated noise power value. The output operating point may also be obtained from the corresponding point on the measured TWTA non-linearity curves. With the input and output operating points obtained, the upper layer signal (of a layered modulation) may be more accurately reconstructed as part of the layered modulation scheme.

[0117] It should be noted that the measurement of non-linearity (i.e., step 1302) may be conducted in a variety of manners as part of the layered modulation scheme. Nonetheless, regardless of the technique used to measure non-linearity, the operating point is estimated along with the measurement for the non-linearity curves. The TWTA non-linearity may be measured at the local IRDs 500, in which case the operating point may be automatically calculated from the nonlinearity measurements. The TWTA non-leariy may also be made at a broadcast/uplink center 104 with the operating point similarly obtained, in which case information on TWTA non-linearity and operating point can be downloaded to individual IRDs 500, such as through the downlink signal 118, to support the layered modulation signal receiving process.

6. Measuring Non-Linearity

[0118] As described above, the measurement of non-linearity (i.e., step 1302) may be conducted in a variety of manners as part of the layered modulation scheme. A first mechanism for TWTA non-linearity measurement is fully described in United States Patent Application Serial No. 10/165,710, entitled "SATELLITE TWTA ON-

LINE NON-LINEARITY MEASUREMENT", filed on June 7, 2002 by Ernest C. Chen. A second measurement mechanism is fully described in United States Provisional Patent Application Serial No. XX/XXX,XXX, entitled "IMPROVING TWTA AM-AM AND AM-PM MEASUREMENT", filed on October 10, 2003, by Ernest C. Chen. The second mechanism represents an improvement over the first mechanism. Non-linearity may be measured in each local IRD 500 (e.g., using a coherent averaging technique that maximizes signal processing gains).

[0119] TWTA non-linearity may be measured locally within individual IRDs. This may, eliminate the need to transmit the non-linearity curves from the broadcast/uplink center 104. TWTA non-linearity can also be measured at the broadcast/uplink center 104 using a similar estimation procedure as that described above but possibly with a larger receive antenna for increased CNR as desired. The IRD 802 which receives the downlink signal 118 (e.g., from the LNB 502) may also include a signal processor which extracts the symbol stream and carrier frequency from the incoming signal and generates an ideal signal, i.e. a signal without the effects of the TWTA and noise. The ideal signal is then used in a comparison processor to produce TWTA characteristic maps (which provide the measurements for TWTA non-linearity). As described herein, the signal processor and comparison processor may be incorporated in IRD 802 within the tuner/demodulator 904, FEC 506. The details concerning the generation of the characteristic maps will be described below in the discussion of FIGs. 14A - 14C.

[0120] Typically, the TWTA characteristic maps comprise measurements of the output amplitude modulation versus the input amplitude modulation (the AM-AM map) and the output phase modulation versus the input amplitude modulation (the AM-PM map). The received signal represents the TWTA amplifier output (plus noise) and the generated ideal signal represents the amplifier input. In addition to diagnosing and monitoring the amplifier, these characteristic maps may then be used

reconstruction of the upper layer signal during the signal reconstruction and cancellation process. Such an offset does not alter the performance of layered modulation processing (or non-linearity compensation performance). In fact, offsetting the operating point may result in a simple and consistent representation of TWTA non-linearity regardless of input saturation, input backoff, etc.

[0128] To offset the measurement curves, the input and output amplitude values (i.e., used during the non-linearity curve measurement) may be rescaled so that the operating point is at a desired reference point (e.g., 0 dB), for both input and output (e.g., thereby providing referenced operating point values). In the log domain, such rescaling may be performed by subtracting the measured (AM) input operating point value (in dB) from all input values (in dB). Likewise, the measured output (AM) operating point value (in dB) may be subtracted from values of all output points (in dB). Thus, by offsetting the measurement curves, the curves may be more easily referenced. In silicon and other hardware implementations, however, it may be desirable to scale the input and output operating points or signals back (e.g., to -3 dB or -5 dB) to avoid signal saturation or fractional value representation overflow for incoming and outgoing signals. The shifting process can be done similarly to that described above.

[0129] With a shifted AM scale ast desired, the output PM value may also be rescaled by subtracting the measured (angular) phase value at the output operating point from the phase value of all output points.

[0130] The results of the above scaling is that the operating point will provide reference values, such as (0 dB, 0 dB) for the AM-AM map, and (0dB, 0°) for the AM-PM map. In this case the input signal must be scaled to 0 dB to match the operating point. To guard against signal saturation errors (and to avoid the need for a look-up-table [LUT] extrapolation), bounding points may be placed beyond the measured signal interval to allow interpolation of the input data (or output testing data) in the testing process that falls outside of the range of a TWTA measurement

WHAT IS CLAIMED IS:

1. A method for determining an input operating point and an output operating point on a non-linear traveling wave tube amplifier (TWTA), comprising:

measuring non-linearity of the TWTA;

computing an input root-mean-square (RMS) value of an input signal used to measure the non-linearity of the TWTA, wherein the RMS value identifies an input operating point of the measured non-linearity of the TWTA; and

obtaining an output operating point.

2. The method of claim 1, wherein the measuring the non-linearity of the TWTA comprises measuring the non-linearity at a local receiver.

3. The method of claim 1, wherein the measuring the non-linearity of the TWTA comprises measuring the non-linearity at a broadcast center.

4. The method of claim 3, further comprising downloading the measured non-linearity and the output operating point to an individual receiver.

5. The method of claim 1, wherein obtaining the output operating point comprises calculating an output RMS value of output signals used in measuring the non-linearity of the TWTA.

6. The method of claim 1, wherein obtaining the output operating point comprises obtaining a corresponding point on the measured TWTA non-linearity based on the input RMS value.

7. The method of claim 1, further comprising reconstructing an upper layer signal of a layered modulation based on the output operating point.

8. The method of claim 1, further comprising offsetting the measured non-linearity to provide referenced operating point values.

9. The method of claim 8, wherein the offsetting comprises scaling an input amplitude value and output amplitude value of the measured non-linearity of the TWTA to place the input and output operating points at desired points.

10. The method of claim 9, wherein the scaling comprises subtracting a measured input operating point value from all input values in a log domain.

11. The method of claim 9, wherein the scaling comprises subtracting a measured output operating point value from all output values in a log domain.

12. The method of claim 9, wherein the scaling comprises subtracting a measured phase value at the output operating point from phase values of all output points used to measure the non-linearity of the TWTA.

13. The method of claim 9, wherein the scaling further comprises:

placing bounding points beyond end points used to measure the non-linearity; and

interpolating output testing data that falls outside of the measured non-linearity based on the bounding points.

14. The method of claim 8, further comprising mapping the input operating point and output operating point to a particular level to avoid signal saturation or fractional value representation overflow.

15. An apparatus for determining an input operating point and an output operating point on a non-linear traveling wave tube amplifier (TWTA), comprising:

means for measuring non-linearity of the TWTA;

means for computing an input root-mean-square (RMS) value of an input signal used to measure the non-linearity of the TWTA, wherein the RMS value identifies an input operating point of the measured non-linearity of the TWTA; and

means for obtaining an output operating point.

16. The apparatus of claim 15, wherein the means for measuring the non-linearity of the TWTA comprises means for measuring the non-linearity at a local receiver.

17. The apparatus of claim 15, wherein the means for measuring the non-linearity of the TWTA comprises means for measuring the non-linearity at a broadcast center.

18. The apparatus of claim 17, further comprising means for downloading the measured non-linearity and the output operating point to an individual receiver.

19. The apparatus of claim 15, wherein the means for obtaining the output operating point comprises means for calculating an output RMS value of output signals used in measuring the non-linearity of the TWTA.

20. The apparatus of claim 15, wherein the means for obtaining the output operating point comprises means for obtaining a corresponding point on the measured TWTA non-linearity based on the input RMS value.

21. The apparatus of claim 15, further comprising means for reconstructing an upper layer signal of a layered modulation based on the output operating point.

22. The apparatus of claim 15, further comprising means for offsetting the measured non-linearity to provide referenced operating point values.

23. The apparatus of claim 22, wherein the means for offsetting comprises means for scaling an input amplitude value and output amplitude value of the measured non-linearity of the TWTA to place the input and output operating point at desired points.

24. The apparatus of claim 23, wherein the means for scaling comprises means for subtracting a measured input operating point value from all input values in a log domain.

25. The apparatus of claim 23, wherein the means for scaling comprises means for subtracting a measured output operating point value from all output values in a log domain.

26. The apparatus of claim 23, wherein the means for scaling comprises means for subtracting a measured phase value at the output operating point from phase values of all output points used to measure the non-linearity of the TWTA.

27. The apparatus of claim 23, wherein the means for scaling further comprises:

means for placing bounding points beyond end points used to measure the non-linearity; and

means for interpolating output testing data that falls outside of the measured non-linearity based on the bounding points.

28. The apparatus of claim 22, further comprising means for mapping the input operating point and output operating point to a particular level to avoid signal saturation or fractional value representation overflow.

29. A system for determining an input operating point and an output operating point on a non-linear traveling wave tube amplifier (TWTA), comprising:

(a) a measuring module configured to:

(1) measure non-linearity of the TWTA; and

(2) obtaining an output operating point; and

(b) a non-linear distortion map module configured to compute an input root-mean-square (RMS) value of an input signal used to measure the non-linearity of the TWTA, wherein the RMS value identifies an input operating point of the measured non-linearity of the TWTA.

30. The system of claim 29, wherein the measuring module is located at a local receiver.

31. The system of claim 29, wherein the measuring module is located at a broadcast center.

32. The system of claim 31, further comprising a receiver configured to download the measured non-linearity and the output operating point.

33. The system of claim 29, wherein the measuring module is configured to obtain the output operating point by calculating an output RMS value of output signals used in measuring the non-linearity of the TWTA.

34. The system of claim 29, wherein the measuring module is configured to obtain the output operating point by obtaining a corresponding point on the measured TWTA non-linearity based on the input RMS value.

35. The system of claim 29, further comprising a receiver configured to reconstruct an upper layer signal of a layered modulation based on the output operating point.

36. The system of claim 29, further comprising a receiver configured to offset the measured non-linearity to provide referenced operating point values.

37. The system of claim 36, wherein the receiver is configured to offset the measured non-linearity by scaling an input amplitude value and output amplitude value of the measured non-linearity of the TWTA to place the input and output operating point at desired points.

38. The system of claim 37, wherein the receiver is configured to scale by subtracting a measured input operating point value from all input values in a log domain.

39. The system of claim 37, wherein the receiver is configured to scale by subtracting a measured output operating point value from all output values in a log domain.

40. The system of claim 37, wherein the receiver is configured to scale by subtracting a measured phase value at the output operating point from phase values of all output points used to measure the non-linearity of the TWTA.

41. The system of claim 37, wherein the receiver is further configured to scale by:

placing bounding points beyond end points used to measure the non-linearity; and

interpolating output testing data that falls outside of the measured non-linearity based on the bounding points.

42. The system of claim 36, wherein the receiver is further configured to map the input operating point and output operating point to a particular level to avoid signal saturation or fractional value representation overflow.